

Psychophysiological Assessment of Fatigue in Commercial Aviation Operations

National Aeronautics and Space Administration



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Introduction

The goal of this study is to improve understanding of crew work hours, workload, sleep, fatigue, and performance, and the relationships between these variables on actual flight deck performance. This study will provide objective measures of physiology and performance, which may benefit investigators in identifying fatigue levels of operators in commercial aviation and provide a way to better design strategies to limit crew fatigue. This research is supported by NASA Ames Research Center Psychophysiology Lab and EasyJet Airline Company, Ltd., Luton, UK.



Figure 1: easyJet Airbus A319

Figure 2: Flight Deck with Pilot (left) and Co-pilot (right)

Background

Pilot fatigue is a significant problem in modern aviation operations mainly because of the unpredictable work hours, long duty periods, circadian disruptions, and insufficient sleep that are commonplace in both civilian and military flight operations². The National Transportation Safety Board has addressed "Human Fatigue" in aviation as one of its main priorities¹. It is the goal of this study to discover new countermeasures to overcome fatigue in pilots.

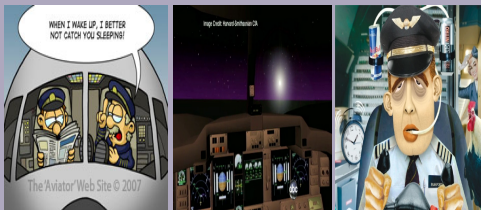


Figure 3: One countermeasure for fatigue is napping

Figure 4: Pilot confuses Venus for plane. Perception can be altered by fatigue

Figure 5: Stimulants (caffeine) is used as a countermeasure for fatigue

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Methods

Twenty commercial pilots (18 men and 2 women, ranging between 22 and 46 years of age) from easyJet volunteered to participate in the study. All pilots flew the Flexible Roster Variation (FRV) schedule: 5 duty days on, 3 days off, 5 duty days on, 2 days off, 5 duty days on. Physiological data were collected on pilots during all 15 duty days throughout the experiment and sent to NASA Ames researchers for subsequent data processing and analyses. Measures recorded during the flights included heart rate, respiration rate, skin temperature, activity and posture acquired with a Zephyr Bioharness ambulatory monitor. Other data were recorded such as sleep log diaries, self-reports of mood states, sleepiness scales (Samn-Perelli), and Performance Vigilance Task (PVT). Activity levels were collected with an Actigraph watch which was worn continuously throughout all duty days and days off.

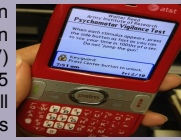


Figure 6: Performance Vigilance Task



Figure 8: Zephyr Bioharness system

Samn-Perelli Scale Rating	Risk level	Controls
1-3	Low	No specific controls necessary. Except in the presence of higher-level indicators of fatigue (i.e., symptoms, errors or incidents).
4-5	Moderate	Initiate moderate fatigue risk mitigation actions
6	High	Initiate high fatigue risk mitigation actions.
7	Very high	Intolerable risk. No individual rostered beyond this threshold.

Figure 9: Sample of Samn-Perelli Scale

Data Analysis

Physiological measures were processed with Dadisp software which included customized functions for removal of motion artifacts (filtering), peak detection algorithms for ECG and respiration signals, and calculating means and standard deviations of each measure. These data were then graphed in Excel to examine relationships to specific crew activities such as phases of flight (take off, cruise, landing) and other metrics such as PVT, sleepiness (Samn-Perelli), mood, and actigraphy. (See Figure 10 below)

Preliminary Results

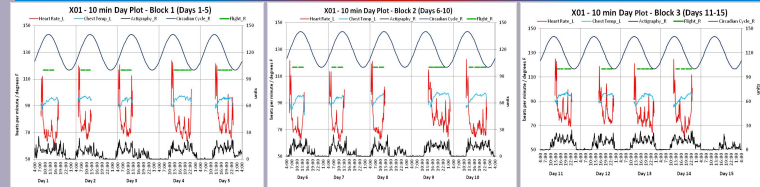


Figure 10: Physiological data (10-minute means) of subject X01 over all flight days

The three graphs above show heart rate (red), chest temperature (light blue), actigraphy (black), a normal 24-hour circadian cycle (dark blue), and actual flight times (green). Each graph represents 5 flight days for viewing similarities and differences in physiological responses over the entire flight roster (15 days). The circadian cycle is shown as a sine wave, the highest point of the sine wave is 12PM and the lowest point is 12AM.

Preliminary Results

Heart rate is measured in beats per minute and chest temperature is measured in degrees Fahrenheit, both are on the left vertical axis. Activity is measured in relative units on the right vertical axis. High activity when awake and low-activity while asleep.



Figure 11: Mood-Alertness Data of Subject X01

Figure 12: Mood-Alertness Data of Subject X06

Readiness to perform is a composite of four measured mood states that include level of motivation, arousal state, ease of concentration, and fatigue level. The graphs above show days when pilots worked early and late shifts. Each pilot completed the mood-alertness scale at the beginning and end of each daily shift. Composite scores of readiness to perform for subjects X01 and X06 are plotted as pre-shift (blue) and post-shift (red). Subject X01's readiness to perform did not show a significant difference from pre- to post-shift, while X06's readiness to perform significantly declined from pre- to post-shift across most days indicating a negative affect on mood states (scores below 5). Further examinations of data of other pilots are underway.

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References

1. "Addressing Human Fatigue." National Transportation Safety Board. Web. 12 July 2012
2. Caldwell, J.A., Mallis, M.M., Caldwell, J.L., Paul, M.A., Miller, J.C., Neri, D.F. "Fatigue Countermeasures in Aviation" Aerospace Medical Association. Aviation, Space, and Environmental Medicine Journal Vol.80, No.1 January 2009



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